location the white noise penalty may exceed 2 dB. H&E further states that laboratory tests by others showed that receiver sensitivity decreased on the order of 0-5.3 dB in the presence of multipath.[127]

53. Other commenting parties generally observe that in the early stages of the DTV transition, multipath was found to be much more difficult for digital TV reception than it was for analog TV reception. dLR, MSW, the NAB and the Network Affiliates state that the fifth generation DTV receivers now commercially available in integrated sets from manufacturers such as LG and Zenith have made substantial improvements in equalizer architecture and can now handle 50 microsecond pre-ghosts and 50 microsecond post-ghosts.[128] dLR submits that a paper by Tim Laud of Zenith reports laboratory results demonstrating fifth generation equalizer capability to handle ghosts of up to 50 microseconds and at a level of 100% (that is, the ghost reflection would be at the same level as the principal signal).[129] dLR, MSW, and NAB note that Tim Laud's paper also reports on field tests on fifth generation receivers in Washington, DC, Ottawa, Canada, and Baltimore, MD, where significant improvements in performance at known "difficult" locations were demonstrated. dLR states that in these field tests, fifth generation receivers showed improvements ranging from an elimination to near elimination of failures (in the Ottawa and Baltimore tests) to a reduction in failures by a factor of three (in the Washington tests). ATI, a manufacturer of electronic components including DTV receiver chips, recommends that in evaluating multipath, the Commission specify the multipath field ensembles set forth in the ATSC's "A/74 Recommended Practice: Receiver Performance Guidelines." It submits that, in contrast to the field ensembles, the "laboratory ensembles" referenced in that document do not provide an adequate basis for predicting how well a receiver will perform in the field.[130]

54. The Network Affiliates submit that because multipath is not a function of signal strength *per se* and because current fifth generation receivers can handle multipath even in generally poor reception conditions, the Commission's DTV planning factors do not need to be adjusted to account for multipath by increasing the value of the minimum field strength assumed to be needed to receive service.[131] The Network Affiliates state that the effects of multipath can be mitigated greatly, if not wholly, by the use of the latest generation receiver, by the use of an outdoor antenna raised to 9 meters/30 feet that will place the antenna above the principal multipath reflectors (*e.g.*, moving vehicles and neighboring residences), and by the use of highly directional antennas with high front-to-back ratios, properly oriented to the strongest desired signal.[132] They point out that the ATSC has stated that "[A]n antenna with a directional

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[127] EchoStar comments, Att. A (Engineering Statement of H&E) at 12 and nn.37-38.(citing Charles Einhoff, "DTV Receiver Performance in the Real World," *Proceedings of the NAB Broadcast Engineering Conference*, 2000, and Bernard Caron, *et al.*, "ATSC 8-VSB Receiver Performance Comparison," *Proceedings of the NAB Broadcast Engineering Conference*, 2000).

[128] MSTV comments, Att. (Engineering Statement of dLR) at 8-9; NAB comments at 39-40 and Att. 1 (Engineering Statement of MSW) at 35-43; Network Affiliates comments at 29-31.

[129] MSTV comments, Att. (Engineering Statement of dLR) at 9 and n.5 (citing Tim Laud, *et al.*, "Performance of 5th Generation 8-VSB Receivers," IEEE Transactions of Consumer Electronics, Vol. 50, No. 4, Nov. 2004, and Yiyan Wu, *et al.*, "An ATSC DTV Receiver With Improved Robustness to Multipath and Distributed Transmission Environments," IEEE Transactions on Broadcasting, Vol. 50, No. 1, March 2004).

[130] ATI comments at 3-5. ATI also indicates that in cooperation with its customers in all affected industries it has developed a robust test procedure and grading system for evaluating multipath based on the A/74 field ensembles. See *id.* at 5-7 and Att. B (ATI White Paper, June 2005).

[131] Network Affiliates comments at 30.

[132] *Id.* at 37.

pattern that gives only a few dB reduction in a specific multipath reflection can dramatically improve the equalizer's performance. Such modest directional performance can be achieved with antennas of consumer-friendly size, especially at UHF."[133] Further, the Network Affiliates observe that there is no principled basis to include multipath in the distant signal eligibility standards since there still remains no objective means to predict or evaluate multipath at any particular location or to evaluate the impact of multipath on local television service generally.

55. ATI submits that the current DTV receiver marketplace offers end-users superior performance that is highly affordable, with market trends projecting increasing affordability and performance as manufacturers integrate the latest generations of DTV receiver chips into their products.[134] ATI and the Network Affiliates state that variations in DTV set prices should play no role in determining whether a household is unserved by an adequate DTV network signal.[135] They state that there is as yet very little consumer penetration of DTV receivers and that most households will therefore have or will acquire DTV receivers with integrated tuners incorporating the latest generational chip design (fifth generation or later), including adaptive equalizers with superior multipath handling performance capabilities. ATI states that neither price nor brand name indicates to consumers the performance of DTV receivers and using the best chips does not necessarily cost more.[136] It submits that as a result, consumers lack sufficient information for purchasing products based on DTV receiver performance. CEA submits that in a market guided by competition and not Government intervention, it should be expected that there will be products that optimize for different parameters.[137] CEA states that these variations are relatively small, as every manufacturer is motivated by competition to build good receivers, but the variations still serve the market. For example, it states that a DTV receiver that has relatively poor weak signal reception as compared to every other receiver in the market might have excellent selectivity and prove to be the ideal receiver for a particular location with closely packed channels. Conversely, CEA states that even if the Commission were to determine that there is very little variation in the ability of existing DTV sets to receive over-the-air signals, those same sets when connected to the many different available antennas and placed in the infinitely complex RF environment will certainly demonstrate a wide variation in reception capability.

56. The Network Affiliates submit that with digital tuners manufactured in mass quantities to satisfy the Commission's digital tuner mandate, the cost of an integrated DTV set is not particularly dependent on the cost of the generation of chip design (for example, fourth generation vs. fifth generation).[138] Instead, they argue that DTV set prices are largely dependent on features such as ATSC format/resolution capabilities (standard definition, enhanced definition, and high definition), screen size, screen technology (CRT, plasma, LCD, DLP), contrast ratio, and integration of other functions such as digital video recorders. The Network Affiliates submit that a survey of the Sharp "Aquos" and LG websites revealed no difference in the type of ATSC tuner included in integrated DTV sets within each manufacturer's product lines. They state that it would be inconsistent with the principal of localism and the objective standards Congress has always imposed on the "unserved household" definition to permit a

[133] *Id.* (citing *ATSC Recommended Practice: Receiver Performance Guidelines*, Doc. A/74 (June 18, 2004) at 24).

[134] ATI comments at 7-9.

[135] *Id.*; Network Affiliates comments at 35-37.

[136] ATI comments at 7-9.

[137] CEA comments at 4-5.

[138] Network Affiliates comments at 36.

satellite carrier to deliver a duplicating distant network signal to a household merely because the household had purchased, probably unknowingly, an inferior DTV set. They note that the current analog "unserved household" definition is not dependent on whether a household buys a $59 13-inch television set or a $400 27-inch set. They state that there is no reasonable basis to make such a distinction in the digital context.

57. *FCC Laboratory Receiver Study*. In order to obtain additional information on the performance of DTV receivers, the Commission's Laboratory conducted a technical measurement study (FCC Study) of a sample of 28 DTV receivers currently available on the market.[139] The objectives of this study were to provide empirical information on the minimum signal level needed by consumer DTV receivers to provide service and whether the minimum signal level needed to provide service varies across DTV receivers by price. It also examined these receivers with respect to their S/N ratios, inferred noise-figures, and performance in the presence of multipath reflections using 47 of the 50 ATSC recommended difficult reflection "captures," or "ensembles."[140] Tests were performed on three TV channels (channels 3, 10, and 30) in order to evaluate performance in the low VHF, high VHF, and UHF bands, respectively. The study receiver sample consisted of 28 products in two categories, set-top-boxes (STBs) and integrated DTV receivers. STBs were included because connection of an STB to an existing television set represents the lowest-cost alternative for DTV reception. All receivers were standard, off-the-shelf consumer products currently on the market and were provided on our request by their manufacturers. In examining the components of DTV receiver performance, the study considered that the minimum signal level needed to receive service is determined by the combined influence of the effective internal noise created by a receiver's internal circuitry (noise figure), signal-to-noise ratio (also termed white noise S/N threshold), and thermal noise, as included in the DTV planning factors. The minimum signal level needed to receive service is the threshold level at which errors become visible in the displayed picture, *i.e.*, threshold of visibility (TOV). Thus, we have:

Minimum Signal at TOV (dBm) = Thermal Noise (dBm) + Noise Figure (dB) + Required CNR (dB)[141]

58. The receivers were measured in the presence of conditions of white noise and of the multipath reflections indicated above. The results were reported by category (STB or integrated receiver) and price range ($370 - $1000, $1001 - $2000, and $2001 - $4200). Brands and model numbers were not reported. The results of this study are described below.

59. The summary results for the minimum signal level factor over all samples in the white noise conditions are shown in Table 1:

[139] *See* "Tests of ATSC 8-VSB Reception Performance of Consumer Digital Television Receivers Available in 2005," OET Report FCC/OET TR 05-1017, Stephen R. Martin, FCC Laboratory Division, November 2, 2005 (*FCC Study*). A copy of this report is attached hereto as Appendix C.

[140] See "*ATSC Recommended Practice: Receiver Performance Guidelines*," ATSC Doc. A/74, Advanced Television System Committee, 17 June 2004. A multipath capture is a recording of the multipath signal pattern that is present at a given location. These are also termed ensembles because a set of specific reflections, *i.e.*, ensemble, will be present at any given location. Three of the 50 recommended captures were excluded from our Laboratory testing because they contain no video content and therefore require specially instrumented receivers for testing.

[141] Receiver noise figures were determined by inference from this equation using the thermal noise figure common to all receivers and the measured S/N for each receiver.

MINIMUM SIGNAL LEVEL AT TOV	Chan 3	Chan 10	Chan 30
Planning factor values (dBm)	-81.0	-81.0	-84.0
Median across all receivers (dBm)	-82.2	-83.2	-83.9
Difference from OET-69 planning factors	-1.2	-2.2	0.1
Deviations of receivers from median (dB)			
--Best performing receiver (dB)	-2.5	-1.7	-1.4
--Worst performing receiver (dB)	12.5	4.3	2.5
--90th percentile receiver (dB)	5.1	3.1	1.3
Standard deviation (dB)	3.7	1.6	0.9
Total span from worst to best receiver (dB)	15.0	6.0	3.9

Table 1 Statistics of Minimum Signal Level at TOV

60. The median minimum signal levels for the study sample were slightly better - by 1.2 dB and 2.2 dB, respectively – than the low-VHF and high-VHF planning factor value (-81.0 dBm) and closely matched the UHF planning value (-84.0 dBm). At low VHF, only 21% of the tested receivers performed more poorly in minimum signal level than the performance measures modeled in OET Bulletin No. 69 by an amount exceeding 1 dB, the approximate tolerance of the measurements.[142] At high VHF and UHF, this figure was 11% and 18% respectively. The variation among receivers at low VHF was fairly large, with a 3.7 dB standard deviation. The two receivers exhibiting the poorest performance were at levels 10.6 dB and 12.5 dB worse than the median. These two receivers, both the same brand, were responsible for much of the variability and omitting them from the results reduces the low VHF standard deviation to 2.3 dB. The third worst performer at low VHF was 6.7 dB above the median. 89% of the receivers (all but three) were within 5.1 dB of the median at low VHF.

61. The performance results for the individual receivers are shown in Figure 1:

[142] The absolute measurement accuracy of the vector signal analyzer on the amplitude range that was used for the measurements was +/- 1.5 dB maximum and +/- 0.5 dB typical.

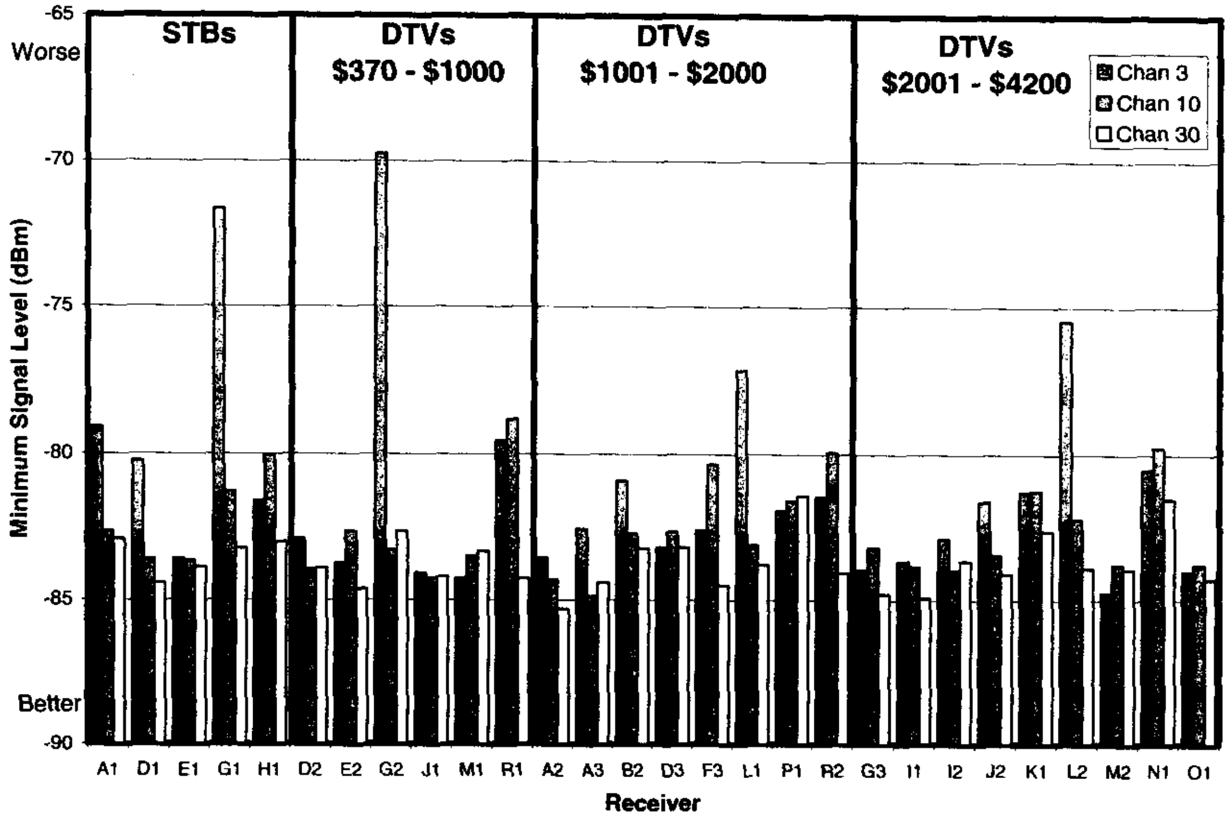

Figure 1. Measured Minimum Signal Level at TOV on Three Channels[143]

62. Looking at the variation of the minimum signal level factor under the benign conditions by product category and price, as shown in Table 2 the FCC Study found:

MINIMUM SIGNAL LEVEL AT TOV (difference from the median by category and price)	Chan 3	Chan 10	Chan 30
Difference of Set-Top Boxes from Overall Median (dB)	2.0	0.5	0.7
Difference of Low-Price DTVs from Overall Median (dB)	-1.1	-0.2	-0.2
Difference of Medium-Price DTVs from Overall Median (dB)	0.0	0.5	0.0
Difference of High-Price DTVs re Overall Median (dB)	-0.7	-0.3	0.0

Table 2 Product-Type Variations of Minimum Signal at TOV

63. This chart shows that the observed variations in minimum signal level across product and price categories were very small. The category medians for high VHF and UHF differ from the overall median by less than 1 dB and for low VHF differ by only 2.0 dB. At low VHF the median performance of the set-top boxes was 2.0 dB worse than the overall median of all receivers and the best median performance was achieved by the low-price DTV receiver category, which slightly outperformed the medium and high-priced categories. At low-VHF, the median of the highest priced sets was only 0.7 dB

[143] The letter/number designations indicate the individual receivers tested.

better than the overall median. In the high VHF and UHF bands the performance differences from the overall median were even less. Most of the differences in median values between categories are so small as to be considered insignificant. We believe that even the largest of these differences would affect perceived performance only in locations where the signal margin was very small and in the general case would not be noticeable to consumers at all.

64. The FCC study found that the white-noise S/N threshold for the median receiver in the sample was 15.3 dB, only 0.1 dB above (worse than) the planning factor value. The white-noise S/N threshold results are summarized in Table 3:

WHITE NOISE S/N THRESHOLD	
Planning Factor Value (dBm)	15.2
Median across all receivers (dBm)	15.3
Difference from OET-69 planning factor	0.1
Deviations of receivers from median (dB)	
--Best performing receiver (dB)	-0.4
--Worst performing receiver (dB)	0.5
--89th percentile receiver (dB)	0.3
Standard deviation (dB)	0.2
Total span from best to worst receiver (dB)	0.8[144]

Table 3 Statistics of White Noise Threshold

65. These results show that the variations in S/N performance among receivers is quite small, with the standard deviation of the S/N measurements across all of the sample receivers amounting to only 0.2 dB. The total range from best to worst performing receiver was 0.8 dB, with the worst performing receiver only 0.5 dB above the median performance. Similar lack of variation in S/N performance was found with respect to price, as shown in Table 4. The median performance of the least expensive receivers, the STBs, was only 0.1 dB worse than the overall median. The median low-cost and mid-cost integrated sets performed at the median, while the median high-cost integrated set performance is only 0.2 dB better than the overall median.

WHITE NOISE THRESHOLD	
Difference of Set-Top Boxes from Overall Median (dB)	0.1
Difference of Low-Price DTVs from Overall Median (dB)	0.0
Difference of Medium-Price DTVs from Overall Median (dB)	0.0
Difference of High-Price DTVs from Overall Median (dB)	-0.2

Table 4 Product-Type/Price Variations of White Noise Threshold

[144] The span does not match the difference between worst and best performing receivers due to the rounding of results to the nearest 0.1 dB.

66. The study derived the receivers' inferred noise figure performance from the measurements of minimum signal level and S/N level under benign conditions and using -106.2 dBm as the value for thermal noise. The inferred noise figure values are shown in Table 5.

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Planning Factor Values	10	10	7
Median across all receivers (dBm)	8.8	7.6	6.9
Difference from OET-69 planning factors	-1.2	-2.4	-0.1
Deviations of receivers from median (dB)			
--Best performing receiver (dB)	-2.5	-1.3	-1.3
--Worst performing receiver (dB)	12.2	4.5	2.6
--89th percentile receiver (dB)	4.5	3.3	1.2
Standard deviation (dB)	3.6	1.6	0.9
Total span from worst to best receiver (dB)	14.7	5.7	3.9

Table 5 Statistics of Receiver Noise Figure

67. These data show that the noise figures for the currently available receivers in the FCC study are generally better than the planning factor values by 1 or 2 dB at low and high VHF and are the same as the planning factor value at UHF. There is considerable variation in the sample receivers' noise figure performance at low VHF, with a standard deviation of 3.6 dB and with two receivers performing at levels 10.3 dB and 12.2 dB worse than the median. However, 89% of the receivers (all but three) were no more than 4.5 dB above (worse than) the median performance at VHF.

68. As shown in Table 6, the observed variations in noise figure with product category and price were small, with the category medians differing from the overall median by less than 1 dB for channels at high VHF and at UHF, but were slightly larger at low VHF. At low VHF the median performance of set-top boxes was 1.7 dB worse than the overall median of all receivers, and the median performance of the highest priced TV category was 0.8 dB better than the median. The best median noise figure, 1.4 dB better than the overall median, occurred in the lowest priced integrated receiver category. Such differences as shown in Table 6 are likely to influence performance only in locations where the signal margin is very small and generally would not be noticeable to consumers.

NOISE FIGURE	Chan 3	Chan 10	Chan 30
Difference of Set-Top Boxes from Overall Median (dB)	1.7	0.1	0.6
Difference of Low-Price DTVs from Overall Median (dB)	-1.4	-0.1	0.1
Difference of Medium-Price DTVs from Overall Median (dB)	0.0	0.4	-0.1
Difference of High-Price DTVs from Overall Median (dB)	-0.8	-0.3	0.0

Table 6 Product-Type/Price Variations of Receiver Noise Figure

69. Finally, measurements of the performance of the sample DTV receivers in the presence of the 47 multipath ensembles are shown in Figure 2:[145]

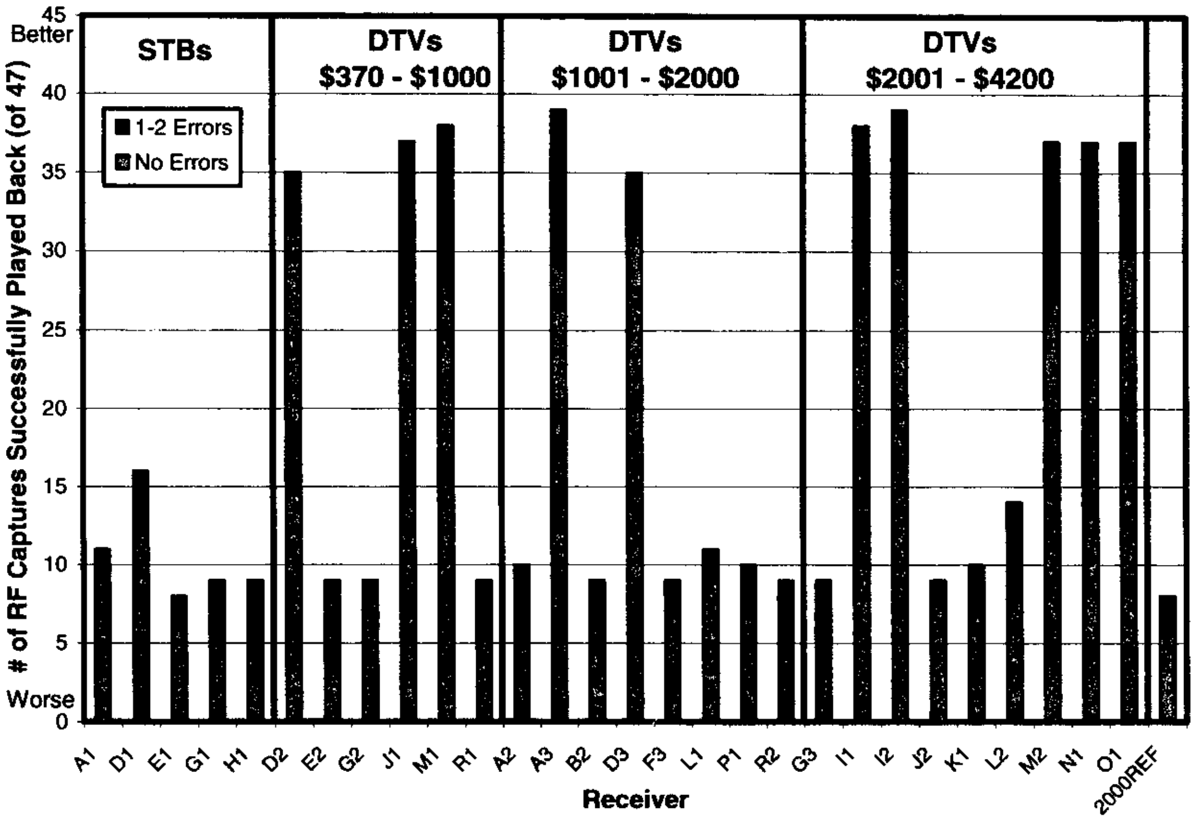

Figure 2 Performance against 47 RF Captures

70. Unlike the results for white noise performance, the results of testing against the RF captures were heavily clustered into two performance tiers.[146] The better performers successfully played 29 captures without error and about 37 captures with two or fewer errors. The lower tier performers successfully played about 7 captures without error and about 9 with two or fewer errors. Except for

[145] In this testing, each receiver was subjected to exactly the same multipath conditions for each capture (the captures are recordings). The lower portion of each bar represents the number of captures that played without a visible error during a single loop, *i.e.*, recording of the capture (a recording of multipath capture is played continuously in a loop). The upper portion of each bar adds the captures that played with no more than two visible errors during a single loop of capture. This chart also includes a bar on the right showing the results for the reference receiver used the FCC field tests in 2000, *see* "A Study of ATSC (8-VSB DTV Coverage in Washington, DC, and Generational Changes in DTV Receiver Performance," (Interim Report) OET Report, FCC/OET TRB-00-2 (2001 FCC Field Test Receiver Study), William H. Inglis and David L. Means, February 2, 2001.

[146] It should be noted that some of the RF captures may contain recording flaws that could prevent error-free demodulation regardless of how advanced the demodulator technology may be, *see FCC Study, supra* note 139, at 6-3. For example, four of the captures for which no tested receiver achieved demodulation free of visual errors were identified by the ATSC as having possible non-linearities caused by high-level adjacent channels overdriving the recording system. These or other potential flaws may preclude a 100% success rate on the 47 captures from ever being achieved by any demodulator. Thus, the FCC Study views the multipath performance data based on these captures to be useful for purposes of comparing receivers, but not as an absolute measure of performance.

receivers D1 and L2, all results fall within ±2 captures of one of these nominal results. Receivers D1 and, perhaps, L2 appear to represent an additional performance level slightly above the lower tier. The upper tier performers provide a significant improvement in the ability to handle the most difficult multipath conditions.[147] The tested receivers in this tier are known to include the latest generation of demodulator chips from at least two of the major DTV chip manufacturers. The results on Figure 2 are summarized in Table 7.

	Number of Consumer Receivers	Number of Captures Played with No Errors	Number of Captures Played with No More Than 2 Errors
Lower Tier	16	7 ±2	9 +2/-1
Lower Tier+	2	8 and 12	14 and 16
Upper Tier	10	29 ±2	37 ±2

Table 7 Number of Captures Successfully Played By Each Performance Tier (Out of 47 Captures)

71. Looking next at the variation of multipath handling performance with product type and price, the FCC Study found that while none of the STBs, which are all of older design, perform at the upper tier level, upper and lower tier performing products appear in all three price categories of integrated receivers. This suggests that multipath handling performance is not a function of price. Among the integrated receivers, the study found that introduction dates in or after March 2005 were consistent with the likelihood of including newer technology. Among the tested receivers that were introduced on or after March 1, 2005, 48% were found to perform at the upper tier level. The study also notes that it is probable that some of the products introduced in this time frame carried over tuner/demodulator designs from a previous generation.

72. In reviewing these results, the FCC Study also considered that there might be some reason to expect that improvements in multipath performance - which is achieved in part by increasing the number of taps in the demodulator's equalizer circuit - might come at the expense of a reduced white noise threshold, because the additional taps could be expected to add noise that is related to carrier amplitude.[148] Figure 3 shows measurements of white noise threshold plotted against multipath performance as measured by the number of RF captures (out of 47) that were successfully played without error. The lower tier of multipath performers (presumably containing earlier generation VSB decoders) had a median S/N threshold of 15.3 dB, slightly worse than the 15.2 dB threshold achieved by the ACATS Grand Alliance prototype receiver. The 15.1 dB median S/N ratio for the upper tier of multipath performers suggests that the characteristic of a worsening of S/N ratio as a trade-off for multipath no longer occurs.

[147] We emphasize that the tested multipath conditions are those known to be most difficult and are not typical of conditions that most households will encounter in receiving digital television service.

[148] Since an automatic gain control would be expected to provide sufficient gain to amplify the input signal - whatever its level - to a fixed level for processing in the demodulator, one would expect that the tap noise generated after this variable amplification would be at a fixed level relative to the DTV signal rather than at a fixed level relative to the antenna input - hence the impact would appear as a degradation to required S/N (white noise threshold) rather than as an increase in noise figure.

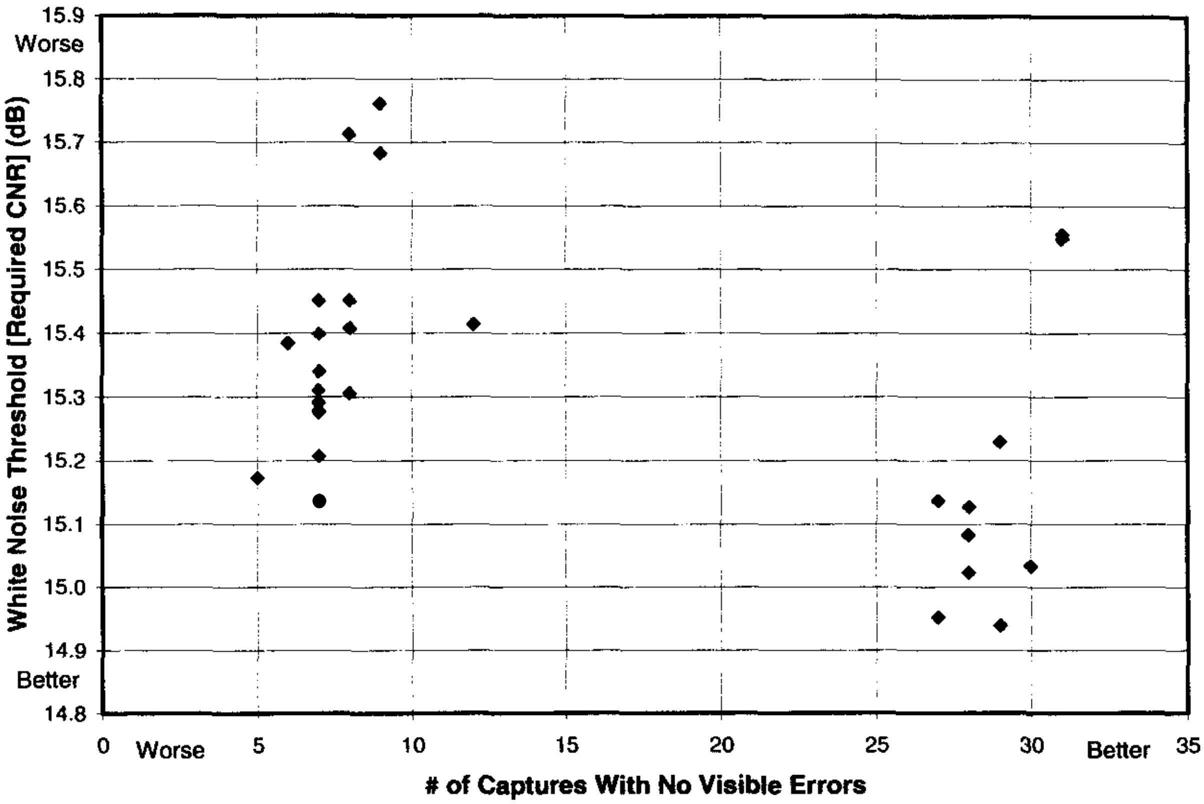

Figure 3 White Noise Threshold Versus Multipath Performance

73. *Evaluation.* Based on our evaluation of both the *Inquiry* record and the FCC study, we conclude that neither the S/N ratio nor the receiver noise figure values in the DTV planning factors should be modified in determining the DTV field signal strength standards to be used for determining whether a household is eligible to receive retransmitted network DTV signals from a satellite service. In answer to Section 339(c)(1)(B)(v), we see no significant variability in the ability of reasonably priced consumer digital television sets to receive over-the-air signals in the high VHF and UHF bands such that some sets are able to display high-quality pictures while others cannot, and the variation that is present does not appear to be closely related to price. We note that in the low VHF band, there were two receivers that were significant outliers and a third receiver that was 6.7 dB above the median. We find that this few number of receivers with high low-VHF thresholds does not obviate our general conclusion that price is not a factor in the availability of DTV receivers that are able to display high-quality pictures.

74. We stated earlier that picture quality does not depend on the level of signal strength. Rather, the importance of the level of signal strength is simply whether service can be received, and the factors that determine that level are a receiver's S/N ratio and noise figure. Our FCC study results indicate that currently available DTV receivers are generally able to provide service with signals at levels very close to those assumed in the planning factors and in a few cases with signals at lower levels. We did find some variation in the reception performance with respect to the minimum signal level needed to provide service, but this was mostly at low VHF. In addition, H&E reported some receivers that need higher minimum signal levels to provide service. We do not view with concern those products needing higher minimum signal levels because it is apparent that the greater portion of products perform generally on a par with the planning factor value. Given that a large number of receivers performed well at signal levels at or close to the minimum signal level assumed by the planning factors, we do not believe that there are

any technical difficulties in providing performance that meets the planning factor target. We believe that it is best to rely on market forces to determine whether those products or perhaps others performing at similarly high threshold levels remain available to consumers. At high VHF and UHF, the variation in reception performance among the receivers in our FCC study was small.

75. As indicated above, we also find no indication that increasing price levels are associated with improved minimum signal level performance. With the exception of set-top boxes, in fact, it appears that there is very little relationship between price and the minimum signal level needed to provide service. Because the set-top boxes studied, and indeed all of those now on the market, are of older designs, we believe that their general design, rather than their price, is the reason for their somewhat lower performance. Thus there do not appear to be any technical reasons that would impede the economical manufacture of products that perform at the expected minimum signal levels currently assumed in the planning factors for the DTV field strength standards.

76. The information on receiver signal-to-noise ratios and noise figures provided in the *Inquiry* record and from our study indicate performance levels consistent with the minimum signal level performance discussed above. This is reasonable given the close relationship of the three measures. It appears that most receivers now on the market exhibit S/N performance within levels very close to the 15.2 dB level assumed in the planning factors, and a few perform slightly better. Again, we do not view those products that are 5 dB or more above the planning factor value for minimum signal level to receive service as an indicator of a deficiency in the planning factor value, given that so many products do perform at or near the expected level. From our FCC study, it appears that most of the variation in the minimum signal level needed to provide service is the result of differences in receiver noise figures rather than S/N ratio. The noise figure variations were larger than the minimum S/N ratio variations by factors ranging from 3.9 dB, in the UHF band, to 14.7 dB in the low VHF band.

77. We conclude that it is not necessary to augment the DTV receiver planning factors with an additional factor for multipath. As EchoStar and others commenting in our Inquiry observe, multipath can pose difficulties for reception of digital television signals and, at the beginning of the DTV transition, receiver adaptive equalizers were not able to adequately process many real world multipath conditions. From the record of our Inquiry and our on-going monitoring of DTV receiver performance, including the testing performed in the FCC study, it is apparent that the current generation of digital TV receivers is able to provide service under most multipath conditions that they may encounter. This can be seen from an earlier field study by the Commission in 2001 that examined DTV reception at a number of sites randomly selected throughout the Washington, DC area. That study, which was based on second and third generation receivers, observed successful reception of DTV service at 99% of the locations where the field strength was at or above the level expected to be needed for service using a mast-mounted antenna at 30 feet. Similarly, that study found successful reception at 85% of the tested locations when using an indoor antenna outdoors at 7-feet. The reason for that level of successful reception with those older receivers is that the number of locations where multipath conditions are difficult is relatively low. The FCC Study indicates that these reception success rates were achieved using a receiver performing in the lower tier of Figure 2. Figure 2 demonstrates that the latest generation of equalizer technology - represented by the upper tier of Figure 2 - provides service when subjected to most of the difficult ATSC multipath ensembles, most of which were recorded with indoor antennas.

78. We also considered the information provided by EchoStar and H&E indicating that, in processing multipath signals, a DTV receiver's adaptive equalizer could generate additional noise that could effectively increase the receiver's noise figure, and thus reduce its sensitivity so that a higher level of input signal could be needed to provide service. It is true that the process of multipath cancellation can cause a "white noise enhancement" - a degradation in performance that causes a higher input S/N to be required in the presence of multipath than in its absence; however, difficult multipath conditions leading

to degradations by as much as 2 dB, as argued by EchoStar and H&E, are not expected to be the norm. The *2001 Field Test Receiver Study* demonstrated that the then-latest generation receiver (with equalizer technology that is now obsolete by two generations) performed better in terms of required S/N in typical multipath conditions than older receivers—indicating a trend toward less degradation in performance in the presence of multipath with successive generations of hardware. That receiver exhibited a median required S/N of 15.9 to 16.0 dB across all of the "coverage sites" tested in those field tests using an outdoor-type antenna. This performance is only 0.7 to 0.8 dB worse than the 15.2-dB S/N in the planning factors.[149] Though the FCC has not tested the newer generations of equalizers in this regard, there is information to suggest that the noise enhancement of the fifth generation is even lower than past generations.[150] Furthermore, the FCC Study notes that, if noise enhancement raises the required S/N to 16.0 dB, when this change is combined with the median measured noise figures of the 28 tested receivers, the overall result is a more optimistic prediction than the value stated in OET Bulletin No. 69 by 0.4 dB and 1.6 dB, respectively, in the low-VHF and high-VHF bands and a less optimistic prediction than the current OET-69 by only 0.7 dB in the UHF band.[151] Accordingly, we do not believe that a factor for multipath should be added to the minimum signal level assumed to be needed to receive DTV service.

3. Other Planning Factors

79. *Thermal Noise and Man-made Noise.* The thermal noise planning factor of -106.2 dBm is based on a 6 MHz bandwidth channel and an assumed temperature of 290° K. As pointed out by dLR and the Network Affiliates, thermal noise is a function of the laws of physics and has not and will not change.[152] We therefore find that the planning factor value for thermal noise is appropriate and should not be changed.

80. In their comments and engineering statement, EchoStar and H&E argue that the digital TV field strength standards should be revised to account for man-made noise.[153] They contend that man-made noise is typically impulse noise from sources such as power line arcing, industrial machinery, automotive ignition systems, appliances having electric motors (vacuums, dishwashers, hair dryers, etc.), devices with switching power supplies (computers), and microwave ovens. They submit that man-made noise was not adequately taken into account in the DTV planning factors, particularly at the low VHF channels. EchoStar and H&E state that, as a result, the Commission did not build in a sufficient margin for noise when it set the DTV signal strength standard for those channels. H&E submits that a 1974 study by NTIA found that in rural locations man-made noise levels are typically above 20 dB and in urban areas such noise is typically above 30 dB near 54 MHz (channel 2).[154] It also states that a more recent 2001

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[149] The "coverage sites" measured in the *2001 Field Test Receiver Study* were selected without regard to multipath conditions. *See 2001 Field Test Receiver Study, supra* note 145.

[150] *See e.g.*, Laud, Tim, Aitken, Mark; Bretl, Wayne; and Kwak, K. Y., "Performance of 5th Generation 8-VSB Receivers", IEEE Transactions on Consumer Electronics, Vol. 50, No. 4, November 2004, which states that the fifth generation receiver includes "techniques for reduced noise enhancement.

[151] *See* FCC Study at 8-4.

[152] MSTV comments, Att. (Engineering Statement of dLR) at 3-4; Network Affiliates comments at 15.

[153] EchoStar comments at 4-5 and Att. A (Engineering Statement of H&E) at 9-11.

[154] EchoStar comments, Att. A (Engineering Statement of H&E) at 10 and n.29 (citing A.D. Spaulding and R.T. Disney, "Man-made radio noise, part 1: estimates for business, residential, and rural areas," NTIA Office of Telecommunications Report OT 74-38, June 1974).

NTIA study found that median noise levels in Boulder, Colorado approached 20 dB at 137 MHz, which it argues implies a median value approaching 30 dB at 54 MHz.[155] H&E contends that if 20 dB or 30 dB of man-made noise is added to the thermal noise floor, some viewers in urban areas will be unable to receive low VHF signals due to excessive man-made noise. EchoStar and H&E therefore submit that the signal strength standard for low VHF channels should be increased by 12-30 dB to account for such noise.

81. In their reply comments, the Network Affiliates state that EchoStar and H&E have misrepresented the results of the NTIA reports.[156] They submit that the 2001 NTIA study cited by EchoStar and H&E actually found man-made noise at 137 MHz (between the low VHF and high VHF bands) to be 17.5 dB in business areas and only 3.6 dB in residential areas.[157] The Network Affiliates state that at UHF frequencies, this study found that it was not possible to differentiate man-made noise from system noise, which indicates that man-made noise is insignificant in the UHF band. They further submit that a 1998 NTIA study found that residential man-made noise had decreased, amounting to no more than 3 or 4 dB in residential areas.[158] They submit that if the 10 dB receiver noise figure for VHF channels is comprised of 5 dB for receiver noise and 5 dB for environmental noise, then the 2001 NTIA study shows that man-made noise at VHF frequencies is within the planning margin (as it also is at UHF frequencies). The Network Affiliates therefore argue that EchoStar and H&E have provided no evidence to warrant adjustment of the digital TV signal strength standards, even at low VHF, for man-made noise. The NAB similarly submits that the 2001 NTIA study relied on by EchoStar in fact says exactly the opposite of what EchoStar claims, namely that man-made noise in residential areas is very low - only 3.6 dB.[159] The NAB further states that if the Commission were to conclude that there is a concern about man-made noise at low VHF channels, the way to address it would be to alter the plans for the DTV transition, for example, by authorizing low VHF channel stations to operate at higher power.[160]

82. We find that the record does not contain any current or substantial studies or other information that would indicate that man-made noise is present in the low VHF or other TV bands at levels that would warrant the addition of this element to the planning factors that underlie the DTV field strength standard. Given the information on residential man-made noise from both the 1974 and 2001 NTIA studies, it appears that the level of man-made noise typically occurring on the low-VHF channels in residential locations is only 3 or 4 dB, a level that is well within the tolerance of the low-VHF noise figure. We also note that TV viewers are likely to become aware of any effects on their TV reception by man-made noise arising from specific devices such as hair dryers, computers, microwave ovens and similar appliances through the simple act of turning those devices on and off. The solution in such cases is to make sure that those devices that might cause interference are turned-off when someone is watching television. Accordingly, we recommend that no revisions be made to the DTV planning factors and field strength standards for man-made noise.

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[155] *Id.* at 10 and n.30 (citing Robert J. Atchaz and Roger A. Dalke, "Man-Made Noise Power Measurements at VHF and UHF Frequencies," NTIA Report No. 02-390, December 2001 (2001 NTIA study)).

[156] Network Affiliates reply comments at 8-10.

[157] *Id.* at 8 and n.25 (citing 2001 NTIA study, *supra* note 154, at 25).

[158] *Id.* at 9 and n.27 (citing R.J. Achatz *et al*, "Man-Made Noise in the 136 to 138 MHz VHF Meteorological Satellite Band," NTIA Report 98-355 (Sept. 1998), at 31).

[159] NAB reply comments at 11 (citing 2001 NTIA study, *supra* note 154, at 25).

[160] *Id.* at 12.

83. *Transmission (Downlead) Line Loss.* The TV receive antenna and receiver are connected by a transmission line that carries the received signal to the receiver's input terminal. The received signal will experience some amount of attenuation as it travels over this line due to the line's inherent resistance and impedance characteristics. Today, most TV receiver systems use 75-ohm shielded cabling for this downlead connection. The 1 dB, 2 dB, and 4 dB downlead line loss figures for low VHF, high VHF, and UHF digital TV channels are based on the assumed use of 50 feet of 75-ohm shielded cable, *i.e.*, RG-6 coaxial cable.

84. In their comments responding to our *Inquiry*, dLR, Jules Cohen, MSW, the NAB and the Network Affiliates submit that the existing downlead loss planning factor values appear reasonable in light of published values for 75-ohm RG-6 cable.[161] The Network Affiliates point out that the ITU has assumed a downlead line loss of 1.1 dB for low-VHF, 1.9 dB for high-VHF, and 3.3 dB for UHF, and that the ITU VHF line loss values are virtually the same as those assumed in the planning factor while the ITU UHF value is lower.[162] In addition, dLR provides the following table of cable specifications for three different cable manufacturers, as shown in Table 7: [163]

Specifications from Manufacturers of Coaxial Cable (75 ohm)				
Frequency	Manufacturer	Cable Type and Model	Attenuation (dB/100 ft)	Attenuation (db/50 ft)
69 MHz (low VHF)	Belden	RG 6/U Model 9116	1.71	0.86
	Channel Master	RG6 9533-500	1.79	0.90
	Coleman	RG 6/U Model 992127	1.9	0.95
194 MHz (high VHF)	Belden	RG 6/U Model 9116	2.73	1.37
	Channel Master	RG6 9533-500	2.89	1.45
	Coleman	RG 6/U Model 992127	3.2	1.6
615 MHz (UHF)	Belden	RG 6/U Model 9116	5.00	2.50
	Channel Master	RG6 9533-500	5.57	2.79

Table 7. Coaxial Cable Performance Specifications

85. dLR points out that in all cases the attenuation values assumed in the downlead loss planning factor exceed those of available products. They therefore submit that the current DTV planning factor values use conservative estimates of transmission line loss. Based on similar information, the NAB states

[161] MSTV comments, Att. (Engineering Statement of dLR) at 4 and 7-8; Network Affiliates comments at 31 and App. (Engineering Statement of Jules Cohen) at 4; and NAB comments at 23-24 and Att. 1 (Engineering Statement of MSW) at 18-19.

[162] Network Affiliates comments at 31 and n.88 (citing *Draft Revision of* Recommendation *ITU-R BT.1368-4* at Table 13).

[163] MSTV comments, Att. (Engineering Statement of dLR) at 7-8 (Table 4).

that it is reasonable to assume that consumer downlead losses will be no greater, and often less than, those specified in the DTV downlead-loss planning factor. MSW indicates that the most expensive RG 6 or RG 59 cable costs about $25 for the typical 50 foot length assumed in the planning factor.

86. In reply comments, EchoStar and H&E argue that it is not realistic to assume that most consumers will use RG 6 cable and that a number of other sources of loss, including baluns (matching transformers), splitters, and impedance mismatch are not accounted for at all.[164] They state that it is not necessarily realistic to assume that consumers will use RG-6 cable and that budget conscious consumers may favor a less expensive alternative that subjects TV signals to greater attenuation. H&E argues that loss from baluns used to connect 300 ohm antennas to 75 ohm cabling results in loss of 0.6 dB at low VHF, 1.5 dB at high VHF and 2.5 dB at UHF. It also argues that the use of splitters that divide signals for delivery to serve more than one outlet will cause losses. H&E further argues that downlead attenuation will increase with the age of the cable. MSW counters that any significant losses from impedance mismatching or baluns can be corrected by use of a mast-mounted low-noise pre-amplifier.[165] They state that the low-noise pre-amplifier would isolate the antenna impedance from that of the downlead cable and the DTV tuner impedance and also provide an output impedance much closer to the 75 ohm cable impedance. In their reply comments, the Network Affiliates state that while it is true that the DTV planning factors do not account for impedance mismatch between the antenna and the receiver front end, EchoStar's claim that the Voltage Standing Wave Ratio (VSWR) on downleads exceeds 2:1 and therefore results in an impedance mismatch loss of 3 dB is not based on empirical studies of consumer equipment. The Network Affiliates submit that a study by Schnelle and Wetmore concluded that the results of tests conducted on professional grade antennas show that it is possible for antennas to have low return and mismatch loss.[166] That report concludes that it is therefore reasonable to conclude that consumer-grade antennas with good impedance matching capabilities are feasible.

87. Based on the record summarized above, we conclude that the current DTV downlead loss planning factor values continue to provide a conservative estimate of the attenuation a received signal will experience between the antenna and receiver. While we recognize that there are additional sources of loss that could reduce the signal level that arrives at a viewer's receiver, those sources are not likely to be present in a typical installation and could be addressed by using better cable or a pre-amplifier at any individual locations where those sources might pose a problem for DTV reception. We note that options for achieving the level of performance specified in the downlead loss planning factor are readily available at reasonable cost. We also understand that in some cases, lower cost downlead cabling with greater attenuation may be used by consumers. In this regard, we observe that in many instances the available DTV signals will be at levels that such cabling will provide satisfactory service. But these considerations do not alter the fact that cabling that meets and indeed exceeds the performance levels assumed in the planning factors is readily available at reasonable prices. Further, if the performance of cabling decreases with age it can and should be replaced in the same manner as any other component whose performance deteriorates or fails over time. We find that any losses from use of baluns would generally be of levels low enough to be compensated for by the margin present in the conservative planning factor values for downlead loss and antenna gain. Similarly, impedance mismatch has not generally been a problem for television reception and, as indicated by MSW, there are solutions available if it were to be so in specific cases. We reject EchoStar and H&E's argument that splitter loss should be included in the planning factors. The issue of whether sufficient signal strength is present for over-the-air rooftop reception is

[164] EchoStar reply comments at 14-15 and Att. A (Engineering Reply Statement of H&E) at 2-3.

[165] NAB reply comments, Att. (Engineering Reply Statement of MSW) 14-15.

[166] *See* D. Schnelle and R.E. Wetmore, "Evaluation of Antenna and Receiver Mismatch Effects on DTV Reception," *48 IEEE Trans. on Broadcasting* 365, 369 (Dec. 2002).

independent of a household's choice to use splitters to distribute signals to multiple TV sets within the home. In any event, "no loss splitters," *i.e.*, distribution splitters, the use of which does not result in any splitter loss, are readily and inexpensively available. Accordingly, we conclude that the current downlead loss planning factor values remain appropriate and recommend that these values not be changed.

88. *Time and Location Variability*. The field strength of digital television signals, like that of other radiofrequency signals, varies by time and location. That is, DTV signal strength will vary over time at the same location and will also vary from location to location. These variations of field strength with time and location are incorporated into the DTV planning model through use of the F(50,90) field strength curves to define a DTV station's noise-limited contour. As indicated above, the F(50,90) level of service means that at the edge of a station's noise-limited contour, 50% or more of the locations can be expected to receive a signal that exceeds the field strength standards at least 90% of the time. It is possible to adjust these percentages by incrementing the field strength values upwards or downwards to reflect a desired level of signal availability. In the planning factors, the values for adjustments to provide different levels of time and location availability were set to zero.[167]

89. In their comments in the *Inquiry*, EchoStar and H&E argue that the time variability assumption that a signal is available at least 90% of the time means that households predicted to be served may not actually have digital TV service for up to five weeks of the year.[168] They argue that an increase in temporal reliability to 99% or better would be prudent until there is greater experience with consumer reception of DTV signals. H&E submits that it collected temporal data on the amplitudes of fourteen DTV signals that could be received at its Sonoma, California offices. It states that it found that variation in signal strength around the median for six of the stations to be about 3.5 dB and 4.9 dB for 90% probability at high VHF and UHF, respectively. It argues that these values must be added to the DTV signal strength standard to achieve 90% and 99% reliability of signal availability respectively. H&E states that its data also show that 4.7 dB and 17.5 dB would need to be added to the high VHF and UHF signal strength standards to increase to the 99% probability level.

90. In their reply comments, MSW, the NAB and the Network Affiliates contend that EchoStar and H&E's claim that 90% reliability means that a viewer will not receive a DTV picture for five weeks a year does not make sense.[169] The Network Affiliates state that the statistical nature of the probability function means that any dips below the digital signal strength threshold will be randomly spaced over very long time periods and thus have no meaning in the sense of a consecutive time period. MSW, the NAB, and the Network Affiliates argue that it would be unfair to broadcasters to change the statistical definition of DTV service at this stage of the transition and that a change to 99% probability would greatly shrink local service areas. The Network Affiliates also argue that H&E's data collection is flawed in that H&E does not explain its methodology or its reasons for reporting data for only six of the fourteen stations it studied. In its reply statement, MSW submits that the results of the daytime field strength measurements taken by H&E ignore the fact that signal strength measurements taken during the daytime

[167] In the case of analog TV service, the planning factors include adjustments to the time variability factors in order to provide for service at 50% of locations 90% of the time. Those values add 6 dB at low VHF, 5 dB at high VHF, and 4 dB at UHF to the F(50,50) contour values to define the analog Grade B contour values. The analog location variability factors were set at zero. This adjustment was not needed for DTV signals as the signal strength standards were based on the F(50,90) levels of signal availability rather than the F(50,50) levels.

[168] EchoStar comments at 9 and Att. A (Engineering Statement of H&E) at 6-7.

[169] NAB reply comments at 7-8 and Att. (Reply Engineering Statement of MSW) at 10; Network Affiliates reply comments at 7-8.

will be lower than at night when the majority of television viewing occurs.[170] It notes that the original TASO studies in the late 1950's, as reported in FCC Report No. R-6602 and which provided the basis for the current FCC statistical propagation curves in Section 73.699 of the rules, were meticulously determined from testing and evaluation over a three year period.[171] MSW states that most of the TASO data was collected over a period of at least six months and sometimes longer than two years, and from a multitude of locations. It therefore argues that a measurement program such as that conducted by H&E, consisting of only six paths taken over a two-week period, is not statistically valid and has little probative value, particularly when additional data was collected but not reported. MSW further submits that, according to FCC Report No. R-6602, signal strength for UHF signals are roughly 2-3 dB lower during the daytime, depending on path distance. As a result, MSW reasons that signal strength measurements during the daytime are likely to be below the median over time.

91. We do not find persuasive reasons in EchoStar's and H&E's submissions for changing the DTV time variability planning factor value. The time variability value is an important factor in determining the area served by a television station and the amount of power needed to cover a planned service area. We believe that this value should not be changed in the absence of a strong indication that its use would be inconsistent with our DTV service model and channel allotment plan. In this regard, we note that radiofrequency signal propagation is always statistical in nature and that the power and/or antenna height needed to approach 100% reliability increases in a non-linear manner. As indicated by MSW, the NAB, and the Network Affiliates, changing the time variability factor values to 99% reliability at this stage of the transition would greatly shrink local DTV service areas. The current values were established based on an industry-Government consensus that relied on the traditional TV service model that worked well for analog TV service (the analog field strength values are based on the F(50, 50) service level with an augmentation to provide F(50, 90) reliability). We also observe, as pointed out by MSW in their reply filing, that the assumed 10% reduction in service availability occurs at the outermost limit of a station's service area; it is not the typical figure for time reliability across a station's entire service area. As the distance to a station's transmitter decreases, the time availability figure increases. Households at the edge of a station's service area can also improve their reception (and thereby reduce or eliminate periods when the station's signal is not available) by mounting their antenna higher, using a higher gain antennas, or using low-noise pre-amplifiers at their antenna.

92. We find that EchoStar's and H&E's argument that the F(50,90) values result in a loss of DTV service reception for more than five weeks a year ignores the fact that any actual interruptions of service tend to occur for short periods in a non-consecutive manner. There also appear to be serious methodological shortcomings in the data collection exercise conducted by H&E, in that it only examined daytime conditions for a short period and for a single location. Moreover, we see no theoretical justification for increasing the signal strength standard by adding a reliability factor amount equal to the variation in DTV signal strength measured over time. Considering all of the information on this issue, we are not persuaded that changes to the time variability planning factor values are warranted. In addition, no commenting party suggested changing the location variability factor and we know of no considerations that would lead us to recommend changing the current zero values for this factor.

93. *Dipole Factor.* The dipole factor expresses the quantitative relationship between the radiofrequency power received by a half-wave dipole antenna and the electrical energy that is present at the terminals of that antenna. This relationship is a function of the laws of physics. Essentially the dipole factor provides for the conversion of radiofrequency power to electrical power. In the DTV planning factors, the dipole factor is expressed in logarithmic form as the relationship between radiofrequency

[170] NAB reply comments, Att. (Reply Engineering Statement of MSW) at 9;

[171] The FCC propagation curves are set forth in Section 73.699 of the Commission's rules, 47 C.F.R. § 73.699.

electric field strength and voltage, assuming a 75-ohm load. As indicated above, the DTV dipole factor values are -118.8 dBm, -120.8 dBm, and -130.8 dBm for low VHF, high VHF, and UHF, respectively.

94. In their comments in the *Inquiry*, the Network Affiliates observe that the dipole factor is dependent on frequency and that the planning factors use a geometric mean frequency of a UHF band extending from 470 MHz to 806 MHz (channels 14-69).[172] They argue that because the core DTV channels extend only to channel 51, rather than 69, the dipole factor for the UHF band should be recalculated on the basis of the geometric mean frequency of the UHF band extending from 470 MHz to 698 MHz (channels 14-51). The Network Affiliates state that the geometric mean frequency of the core DTV UHF band is 573 MHz, which results in a dipole factor of -130.2 dB, or 0.6 dB lower than the current UHF dipole planning factor value. The effect of such a change would be to reduce the field signal strength level needed to receive UHF DTV signals by 0.6 dB, to 83.4 dBm.

95. While the geometric frequency of the UHF band will indeed change from 615 MHz to 573 MHz at the end of the transition when all UHF DTV stations will operate in the channels 14-51 core spectrum, as indicated by the Network Affiliates, we do not believe that a change in the UHF dipole planning factor value is warranted. Initially, we note that the planning factors specify a single dipole factor value for the UHF band and additional single values for the low VHF and high VHF bands. Reducing the UHF dipole planning factor value would have the effect of reducing the minimum signal strength accepted as needed to receive service and thereby increase the geographic areas served by stations. The true dipole values are specific to each individual channel, as the conversion factor from electromagnetic energy to electric energy through an antenna varies with frequency. Thus, the planning factor dipole values for each channel range are only approximations of the actual dipole values for each channel. We note that unlike the planning factors, the Longley-Rice Model in OET Bulletin No. 69 includes a dipole modification factor that is added to the planning factor value so that DTV service area computations within a station's noise-limited contour are made using the true dipole factor.[173] Thus, modification of the dipole factor to reflect the geometric mean frequency of the core spectrum would not have any effect on the actual service areas of individual DTV stations, because nothing in the physical operation of the stations would be changed. Given that the difference in the current UHF dipole factor and the dipole factor for the core spectrum UHF channels is only .6 dB and the fact that changing this planning factor would not actually affect the minimum threshold level of signal needed to receive individual stations, we find that this planning factor should not be changed. We conclude that the interests of maintaining stability in the service areas of TV stations outweigh the benefits of providing a small apparent reduction in the level of signal needed to receive UHF DTV stations.[174]

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[172] Network Affiliates comments at 16.

[173] *See* OET Bulletin No. 69 at 3-4.

[174] We note that Jules Cohen, the consulting engineer for Network Affiliates, appears to agree with this conclusion. *See* Network Affiliates comments, Appendix (Engineering Statement of Jules Cohen) at 5 ("in light of an absence of need to change other [planning factors]," the dipole factor is not proposed to be changed).

4. Additional Considerations

96. In response to Section 339(c)(1)(B)(vi) we also considered whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter in the digital television field strength standards. Our assessment of building loss in the case of indoor antennas as a potential factor in the digital television field strength standards are set forth in the discussion above concerning antenna gain, orientation, and placement. There, we observe that building losses are dependent on the materials with which the building is constructed and the location of an antenna within the building. Because of these variabilities, we conclude that it would be impractical to establish an indoor digital television field strength standard. We also observe that while the location of buildings with respect to outdoor antennas may have an effect on the signal strength that reaches an outdoor antenna, in most cases there will be many paths by which a digital television signal can generally be expected to reach that antenna despite the presence of buildings, other man-made clutter, and vegetation in the signal path. We therefore conclude that building loss should not be considered in the digital television field strength standard. On the other hand, blockage from buildings, other man-made clutter and vegetation is likely to be a factor in the digital television signal strength that is available at individual locations. These elements were previously factored into the predictive model used for determining analog television field strengths at individual locations, and we find that it would be appropriate to include those same factors into a predictive model for determining digital television field strengths at individual locations. That issue is discussed in the section below on the digital television predictive model.

97. Looking at the performance of DTV receivers in the presence of interfering signals, we observe that in general a radio receiver's immunity to interference is dependent on a number of factors in its technical design and, in addition, on the characteristics of the signals it is designed to receive. These factors may be closely related and possibly interdependent, and a receiver's performance on one factor may often affect its performance on others. The factors determining receiver immunity performance generally include selectivity, sensitivity, dynamic range, automatic RF gain control, shielding, modulation method, and signal processing. Receiver selectivity is the ability to isolate and acquire the desired signal from among all of the undesired signals that may be present on other channels. Sensitivity is the measure of a receiver's ability to receive signals of low strength. Greater sensitivity means a receiver can pick up weaker signals.[175] Dynamic range is the range of the highest and lowest received signal strength levels over which the receiver can satisfactorily operate. The upper side of a receiver's dynamic range determines how strong a received signal can be before failure due to overloading occurs. Automatic RF gain control allows a receiver to adjust the level of a received signal as it appears at the unit's signal processing and demodulation sections.

98. In the *Inquiry*, we noted that many factors can affect the reception of radio frequency signals and the ability of a receiver to resolve these signals and produce a picture.[176] Most notably, interference from both co-channel and adjacent channel TV transmitters could cause interference to the desired signal. Selectivity is a central factor in the control of adjacent channel interference.[177] However, we also noted

[175] Greater sensitivity can also result in reception of unwanted signals at low levels that then must be eliminated or attenuated by the selectivity characteristics of the receiver.

[176] *Inquiry, supra* note 23, at ¶ 19.

[177] There are several ways to describe the selectivity of a radio receiver. One way is to simply give the bandwidth of the receiver over which its response level is within 3 dB of its response level at the center frequency of the desired signal. This measure is often termed the "bandwidth over the -3db points." This bandwidth, however, is not necessarily a good means of determining how well the receiver will reject unwanted frequencies.

that different receiver designs may account for the differing abilities of receivers to reject greater or lesser amounts of interference. We requested comment on the interference rejection capabilities of digital TV receivers and satellite set-top-boxes with built-in off-air receivers.

99. In their comments responding to our *Inquiry*, ATI notes that in 2003 the Commission suggested that the ATSC develop voluntary standards for DTV receiver performance[178] and that in response the ATSC developed such standards and published them in its "A/74 Recommended Practice: Receiver Performance Guidelines" (A/74 Recommended Practice).[179] The ATSC recommended DTV receiver performance standards were developed by industry parties representing broadcasters, consumer electronics manufacturers, consumers, and others. These standards address DTV receiver performance in the areas of sensitivity, multisignal overload, phase noise, selectivity, multipath, antenna interface and consumer interface. ATI recommends that the Commission adopt the ATSC A/74 Recommended Practice for receiver performance because it reflects this cross-industry agreement and provides the most appropriate and accepted parameters for evaluating receiver performance.

100. H&E submits that two respected engineers have expressed concern about interference from adjacent channel intermodulation interference sources.[180] It further states that it is aware of several failures of DTV reception that are attributable to "image interference" from strong undesired signals and notes that image interference (typically resulting from signals seven or eight channels above or below the desired channel) is not currently addressed by the Commission's DTV allotment standards. H&E states that while there currently is not enough information to assess typical receiver performance with regard to image interference, the existing protection ratios as documented in OET Bulletin No. 69 might be presumptively used to determine the presence of interference and provide reasonable goals for DTV receiver designs.

101. We observe that a receiver's ability to provide service in the presence of interfering signals is not relevant to the field strength needed to provide service. While the presence of other signals on the same or adjacent channels does have the potential for causing interference that can cause loss of service, the effects of other signals are a separate matter from the basic functioning of a receiver in an interference-free environment that forms the basis for the Commission's field strength standards. In general, interference caused by the presence of a signal in the same channel as the desired channel (co-channel interference) is a problem that cannot be addressed by receiver improvements and must be addressed by avoidance of signal overlap. Interference from signals one or more channels removed from the desired channel (adjacent channel interference), however, can be addressed by designing receivers to be more selective and using antennas that provide discrimination against unwanted signals through directivity.

Consequently, it is common to give the receiver bandwidth at two levels of attenuation; for example, -6dB and -60 dB. The ratio of these two bandwidths is called the shape factor. Ideally, the two bandwidths would be equal and the shape factor would be one. However, this value is very difficult to achieve in a practical circuit.

[178] *See* Interference Immunity Performance Specifications for Radio Receivers; Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, *Notice of Inquiry* in ET Docket No. 03-65 and MM Docket No. 00-39, 18 FCC Rcd 6039 (2003).

[179] *See* "A/74 Recommended Practice: Receiver Performance Guidelines," Advanced Television Systems Committee, Inc., June 18, 2004.

[180] H&E citing Oded Bendov, "Interference to DTV Reception by First Adjacent Channels," *IEEE Trans. on Broadcasting*, Vol. 51, No. 1, March 2005 and Charles W. Rhodes, "Interference between Television Signals Due to Intermodulation in Receiver Front-Ends," *IEEE Trans. on Broadcasting*, Vol. 51, No. 1, March 2005.

102. As a general matter, the Commission has traditionally refrained from attempting to regulate the ability of receivers to provide service in the presence of adjacent channels. Instead, it has relied on market forces to direct manufacturers to produce television sets that provide satisfactory service in the RF environment allowed by the Commission's rules. In this regard, the rules provide engineering and inter-station spacing standards that limit the signal strength of co-channel and adjacent channel signals that are present in a licensed station's service area. Manufacturers are then free to build receivers to whatever levels of performance they choose with respect to selectivity and other performance characteristics. Market forces provide incentives for manufacturers to design products that will operate within the RF environment that may exist in an area. If a receiver does not provide service in that environment, a consumer would very likely return it to the place of purchase thereby providing economic feedback to the manufacturer.

103. Over the years, this approach has worked very well and the Commission has not found it necessary to establish performance standards for TV receivers to avoid interference. For example, most recently in the 1999-2000 time frame it became apparent that the performance of the active equalizer function of digital television receivers that provides immunity to multipath was not adequate in the early models of receivers.[181] Manufacturers responded to this performance problem by improving the performance of the adaptive equalizer function. That improvement effort, which is still on-going, has now produced the fifth generation DTV receivers that are able to provide satisfactory performance under most conditions of multipath. We continue to believe that reliance on market forces is the most appropriate approach for ensuring that DTV receivers perform satisfactorily with regard to their ability to handle interfering signals. That approach allows manufacturers the freedom to design products that meet a variety of consumer needs and also to implement changes that may be needed to implement new components, address a new understanding of the television signal environment, or meet changes in the consumer market. While we understand that a few parties may be concerned about the interference immunity performance of DTV receivers, the DTV receiver products currently on the market generally appear to be performing satisfactorily in rejecting interference. In this regard, we have not seen any obvious problems with the receivers on the market now failing to provide service because of interference. Thus, it appears that market forces are adequately providing for interference immunity.

104. We do believe that the ATSC A/74 Recommended Practice provides a strong benchmark for the performance capabilities. The standards in this document provide clear performance targets for the development of DTV receivers that provide quality performance within an economically feasible cost structure. While we strongly encourage manufacturers to consider and adhere to the performance standards in A/74 Recommended Practice, we do not find any compelling reason to make compliance with those or any other DTV receiver performance standards mandatory to ensure that television service is not affected by interference at this time. Accordingly, we do not recommend that Congress take any action with regard to the digital television field strength standards or otherwise adjust the methods for determining whether it is possible to receive television signals at a location to account for receiver interference performance.

C. Alternative Standards to Field Strength

105. In Section 339(c)(1)(B)(iii), Congress requested that the Commission consider whether a standard should be used other than the presence of a signal of a certain strength to ensure that a household can receive a high-quality picture using antennas of reasonable cost and ease of installation. In response to the *Inquiry*, CEA states that it believes that the presence of a signal of a certain strength is the right

[181] *See* Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, *Report and Order and Further Notice of Proposed Rule Making*, 16 FCC Rcd 5946 (2001). That decision also discusses the Commission's approach to regulation of television receiver performance.

level of involvement of the FCC in determining the availability of TV service.[182] It states that going beyond that approach would invite a quagmire of assessing reasonableness, cost effectiveness, and ease of installation. The NAB similarly submits that field strength standards are better than alternative approaches such as those that would use a "picture quality" test because qualitative tests involve subjective judgments. It argues that because the results of field testing by experienced engineers show that objective signal strength is an excellent proxy for the availability of a high-quality digital picture, there is no need for such judgments to be made. Based on our long experience with radio services, we do not believe that any alternative to field strength standards would provide a better indicator of whether a household can receive service. In this regard, we note that the DTV field strength standards in fact incorporate a large number of considerations, as evidenced by the technical criteria represented in the planning factors. We believe that the numerous elements that affect reception of digital television service are adequately and appropriately included in the standard through the DTV planning factors. Accordingly, we recommend that the current plan of field strength values and their specification remain the standards for determining whether digital television signals can be received. We further recommend that the Congress continue to allow the Commission to modify or replace those standards through the rule making process as may be necessary. We believe the flexibility of that process provides an adequate means for both identifying when and if changes are necessary and for developing appropriate revisions.

D. Summary Field Strength Standards Recommendations

106. From the above discussion, we observe that households face a wide range of situations in receiving over-the-air digital television service, just as they always have with analog television service. In the variability of receive sites there are some cases, *i.e.*, where a station's signal is particularly weak, in which a household that is within a TV station's service area may not be able to receive service using the typical TV reception system. In those cases there are readily available options to improve the capability of the households' receive systems to obtain over-the-air service. In other cases, *i.e.*, where a station's signal is particularly strong, a household may not need a receive system with the full capabilities of the typical receive system and, for example, may be able to use an indoor antenna. Given the ready availability of equipment for receiving service in locations with different levels of available field strength and the administrative efficiency of providing a simple, easy to understand and apply definition of DTV service area and signal availability, we continue to believe that it is appropriate to define digital television signal availability/service area using field strength standards that are specified on the basis of a typical receive system. For the reasons indicated in this discussion above, we believe any other approach that would introduce more variables and complexity could lead to subjectivity and arbitrariness in making determinations of signal availability. We also conclude that there is no alternative approach to field strength standards that would provide a more accurate measure of service area and/or signal availability at individual locations.

107. The variability that exists in receive conditions extends to the performance of the specific elements of the receive systems used by consumers. For example, a given household may not need to use a downlead that approaches 50 feet or the antenna it uses may provide less gain than that specified in the planning factors. In the evaluations above, we balanced the variability of these situations. The planning factor values were established as typical values that could be expected in a household's TV reception system. We also believe that the planning factor values as specified are in some instances, such as antenna gain, downlead loss, and receiver noise figure somewhat conservative. These values appear to provide a few dB of additional margin in the summation of factors that determine the minimum signal level needed for service so that the level of signal that is needed for service would be a little lower. On the other hand, certain other factors such as downlead impedance mismatch, balun loss, and in some cases

[182] *See* CEA comments at 3-4.

additional noise from adaptive equalizer operation may tend to increase the minimum signal level needed for service by a few dB. We believe that these plus and minus elements generally negate one another and should have no impact on the basic calculation of the minimum signal level needed for service.

108. We therefore make the following recommendations with respect to the digital television field strength standards for use in determining households' eligibility to receive distant network television signals that are retransmitted by satellite:

- Maintain the approach that specifies DTV service areas on the basis of field strength standards for the low-VHF, high-VHF, and UHF bands;
- Maintain the existing planning factors in determining the DTV field strength standard,
- Do not augment the field strength standards to account for indoor antennas, antenna rotational capability, receiver price, external interference sources including undesired from both digital and analog television stations, building loss, foliage, man-made clutter;
- Maintain the existing DTV field strength standards for use in determining the availability of DTV service at the locations of individual households.

IV. DIGITAL TELEVISION FIELD STRENGTH MEASUREMENT PROCEDURES

109. The Commission has standardized procedures for measuring the field strength of analog television signals at individual locations.[183] Now, as we are on the horizon of transitioning to digital television, Congress has asked us to consider whether, for evaluating if a household is unserved for purposes of determining eligibility to receive distant network signals retransmitted from a satellite service, different field strength measurement procedures are necessary.[184] Specifically, in Section 339(c)(1)(B)(ii) of the Communications Act, as amended by the SHVERA, Congress asked the Commission to consider whether Section 73.686(d) of the Commission's rules should be amended to create different procedures for determining if the requisite digital signal strength is present than for determining if the requisite analog signal strength is present.

110. Currently, Section 73.686(d)(1)(i) requires that field strength measurements be made using either a half-wave dipole antenna that is tuned to the station's visual carrier frequency or a gain antenna, provided that the antenna factor for the channel under test is known.[185] In addition, the rules specify that the intermediate frequency (i.f.) bandwidth of the measuring instrumentation be at least 200 kilohertz but no more than 1,000 kilohertz.[186] Measurements are to be taken in five locations, preferably close to the actual antenna or where one is likely to be mounted.[187] In addition, the rules specify that the measurement antenna is to be raised to a height of 6.1 meters (20 feet) above ground for one story structures and 9.1 meters (30 feet) above ground for two story or taller structures.[188] Finally, because the current rule was written specifically to determine the field strength of analog TV signals, the procedures specify that the field strength measurement is to be made on the visual carrier.[189] The measured values are then to be compared to the field strength that defines the Grade B contour for the station in question to determine if the measured location is receiving a signal of sufficient intensity for analog television reception.

111. In the *Inquiry*, the Commission recognized that the rules defining measurement procedures for analog television cannot simply be applied to digital television signals.[190] Thus, some modifications are necessary. As described above, the current measurement procedure requires that measurements be conducted on the visual carrier. Digital television signals, however, do not contain a visual carrier. Instead, all information – video and audio – is encoded within the bit stream that makes up the entire signal. We stated, therefore, that a new rule would be needed to deal with the measurement of digital television signals, at least insofar as it relates to the specific frequency on which to tune.[191] The Commission pointed out that the digital television signal contains a pilot signal that is used by a receiver's

[183] *See* 47 C.F.R. § 73.686(d); *see* also, *SHVA Report and Order*, 14 FCC Rcd 2654 at ¶ 8.

[184] 47 U.S.C. 339(c)(1)(B)(ii), *as amended by* Section 204(b) of the SHVERA.

[185] *See* 47 CFR 73.686(d)(1)(i).

[186] *See* 47 C.F.R. § 73.686(d)(2)(i).

[187] *See* 47 C.F.R. § 73.686(d)(1)(ii).

[188] *See* 47 C.F.R. § 73.686(d)(2)(iii).

[189] *See* 47 C.F.R. §§ 73.686(d)(1)(i) and 73.686(d)(2)(i).

[190] *Inquiry*, *supra* note 23, at ¶ 13.

[191] *Id.*

tuner to lock onto the desired received signal and suggested that this signal could be used for measurement purposes.[192] More generally, the Commission asked commenting parties to provide information on the signal characteristics to which the measurement instrumentation should be tuned (*e.g.*, pilot signal, center of channel, etc.). We also noted that the portion of the current rule for determining if a household is unserved by comparing the measured signal strength value to the Grade B contour field strength is not appropriate for digital television signals. For digital television stations, instead of a contour defined by Grade B signal intensity, the noise-limited service contour, as defined in Section 73.622(e) of the Commission's Rules, is used.[193]

112. In addition to the Commission's request for comment regarding the aforementioned differences between analog and digital television signals, comment was also sought on other portions of the analog signal strength measurement rule and their applicability to digital television signals. We asked whether the i.f. bandwidth of the measurement equipment that is specified for analog television signals is also appropriate for digital TV signals. We further requested comment on the height that should be specified for the receiving antenna equipment to measure outdoor signals, and on whether specific procedures should be created for measuring the availability of indoor signals. Regarding indoor measurements, we asked if the Commission were to adopt such procedures, what criteria should be applied to determine whether an indoor or an outdoor measurement would be performed at a specific location. Finally, we asked if there are any other aspects of our measurement procedures that need to be modified for the purpose of determining if households are unserved by an adequate digital TV signal.

113. Congress, in SHVERA, also requested that the Commission consider whether to account for factors such as building loss, external interference sources, or undesired signals from both digital television and analog television stations using either the same or adjacent channels in nearby markets, foliage, and man-made clutter. In the *Inquiry*, we requested that commenting parties provide information regarding how to account for these factors.[194] We noted that many factors can affect the reception of radio frequency signals such as interference from both co-channel and adjacent channel TV transmitters. We also noted that other external forces can affect the signal that ultimately reaches a TV receiver. These include natural and man-made structures that lie between the transmitter and the receiver. We observed that these obstructions can affect a signal in various ways such as by attenuating the signal so that the actual signal received is weaker than that predicted in the absence of any such obstructions or by creating multipath interference, which occurs when a signal bounces off structures and the main and reflected signals arrive at the receiver at different times.

114. *Inquiry Record.* NAB and the Network Affiliates state that existing methods for measuring field intensity at individual locations will, with a few minor modifications, work well for digital signals.[195] Many of the suggested modifications are straightforward and are a direct result of the questions the Commission asked. For example, NAB points out that the rules for digital television measurements must reference the appropriate noise-limited field strength value rather than the Grade B contour.[196]

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[192] The pilot signal is located 0.31 MHz inside the lower band edge of the DTV channel and has a power level that is 3 dB lower than the average power of the DTV signal.

[193] 47 CFR § 73.622(e); *see also* 47 CFR § 73.625(b) (determining coverage).

[194] *Inquiry, supra* note 23, at ¶ 20.

[195] NAB comments at 25; Network Affiliates comments at 38.

[196] NAB comments at 26.

115. In the *Inquiry*, the Commission observed that a change was necessary regarding how to actually measure the digital television signal strength given that the current rule is analog specific. The NAB and the Network Affiliates state that the Commission's suggestion to substitute a measurement of the pilot signal of a digital television signal for the analog measurement of the visual carrier would not be appropriate.[197] They state that the problem with using the pilot signal is that in practice, multipath can create fluctuations of ±10 dB which in turn would cause corresponding measurement errors.[198] Instead, the NAB and the Network Affiliates specify that consistent with the Commission's definition of the power of a digital television signal, measurements should be conducted by tuning to the center of the digital television RF channel and measuring the integrated average power over the signal's 6 megahertz bandwidth. Several methods for performing this measurement are suggested: 1) using a swept-tuned spectrum analyzer with a variety of small i.f. bandwidths; 2) using a calibrated field strength meter that has one fixed narrow bandwidth, but can be swept across the entire 6 megahertz band; and 3) using a calibrated fixed tuned receiver that has an i.f. bandwidth equal to the 6 megahertz digital television channel.[199]

116. The Network Affiliates and the NAB both suggest that the measurement system include a directional antenna rather than a simple dipole. Use of such an antenna, they assert, will help ameliorate the effects of multipath and also ensure that the measured power levels are sufficiently high to permit accurate measurement at all channel ranges.[200] The NAB suggests use of a calibrated directional antenna with a front-to-back ratio protection consistent with Commission planning assumptions.

117. On another point, the Network affiliates and the NAB both suggest that the current procedure remain unchanged with respect to measurement height. They state that measurements should continue to be made outside at a height of 6.1 meters (20 feet) for a one-story home and 9.1 meters (30 feet) for a two-story home.[201] While not disagreeing with the position of the Network Affiliates and the NAB on this point for outdoor measurements, EchoStar suggests that we establish indoor testing procedures. EchoStar states that because it is not practical for many households, such as those living in apartments, to use an outdoor antenna, procedures for testing with an indoor antenna are needed and that indoor testing should be required.[202] To bolster this position, it references the statement from H&E which claims that due to limitations on physical size, indoor antennas have gain of about 9 dB below those for outdoor antennas. Therefore, EchoStar and H&E offer that indoor testing should be done using a typical indoor antenna or, if a professional antenna were used, then the signal test result should be reduced by 9 dB or more to account for the lower gain of the indoor antennas.[203] The NAB and the Network Affiliates disagree. For example, the NAB states that the Commission should not permit testing of indoor antennas as it would be inconsistent with the premise of the DTV transition that households will make the same efforts to receive digital signals that they have historically made to receive analog signals.[204] Further,

[197] NAB comments at 26-27; Network Affiliates comments at 38-39.

[198] *E.g.*, NAB comments, Att. 1 (Engineering Statement of MSW) at 21.

[199] *Id.* at 20-21.

[200] *Id.* at 38.

[201] NAB comments at 27; Network Affiliates comments at 39.

[202] EchoStar comments at 6-7.

[203] *Id.* at 7.

[204] NAB comments at 27.